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As a renewable energy hydropower for sustainable development in Turkey

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ABSTRACT

The most important renewable sources are hydropower, biomass, geothermal, solar and wind. Turkey's geographical location has several advantages for extensive use of most of these renewable energy sources. In recently, electricity has demand increased significantly; it is the fastest growing end-use of energy. Therefore, technical, economic and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix. In the world, particularly in the developing countries renewable energy resources appear to be one of the most efficient and effective solutions for sustainable energy development in Turkey. Turkey's geographical location has several advantages for extensive use of most of the renewable energy sources. This paper deals with policies to meet increasing energy and electricity demand for sustainable energy development in Turkey. Turkey has a total gross hydropower potential of 433 GWh/year, but only 125 GWh/year of the total hydroelectric potential of Turkey can be economically used.

Contents

1. Introduction

Hydropower contributes one-fifth of the world's power generation. In fact, it provides the majority of supply in 55 countries. For several countries, hydropower is the only domestic energy resource. Its present role in electricity generation is therefore substantially greater than any other renewable energy technology, and the remaining potential, especially in the less developed countries such as Turkey, is vast. While it is not a panacea, in that it is restricted to sites with available water and appropriate geomorphology, hydropower's flexibility and proven technology sets it apart from other renewable energy sources [16,19,35].

Hydropower is available in a broad range of project scales and types. Projects can be designed to suit particular needs and specific site conditions. As hydropower does not consume or pollute the water it uses to generate power, it leaves this vital resource available for other uses. At the same time, the revenues generated through electricity sales can finance other infrastructure essential for human welfare. This can include drinking water supply systems, irrigation schemes for food production, infrastructures enhancing navigation, recreational facilities and ecotourism [14,16,34–36].

Water is a vital resource that supports all forms of life on earth. Unfortunately, it is not evenly distributed by season or geographical region. Some parts of the world are prone to drought, making water a particularly scarce and precious commodity. In other parts of the world, floods that cause loss of life and property are major problems. Throughout history, dams and reservoirs have been used successfully in collecting, storing and managing water needed to

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Table 1
World renewables indicators in 2007.

Country/region	Total primary energy supply (Mtoe)	Of which renewables (Mtoe)	Share of renewables in TPES[a] (%)	Share of main fuel categories in total renewables (%)		
				Hydro	Geothermal, solar, wind, tide	Renewable combustibles and waste
Africa	630.9	304.6	48.3	2.7	0.3	97.0
Latin America	551.1	168.3	30.5	34.2	1.6	64.2
Asia	1377.0	375.2	27.2	5.9	4.3	89.8
China	1969.5	241.3	12.3	17.3	2.1	80.6
Non-OECD Europe	105.8	10.1	9.6	37.6	1.3	61.1
Former Soviet Union	1015.6	30.7	3.0	69.3	1.5	29.2
Middle East	548.3	4.0	0.7	48.2	21.7	30.1
OECD	5497.1	357.9	6.5	30.2	13.2	56.6
Total World	12026.0	1492.2	12.4	17.7	4.9	77.3

[a] TPES: total primary energy supply.

sustain civilization. Hydropower often supports other essential water services such as irrigation, flood control and drinking water supplies [2,36].

2. Development of global renewables

In 2007, world total primary energy supply (TPES) was 12,026 Mtoe, of which 12.4%, or 1492 Mtoe, was produced from renewable energy sources (see Tables 1 and 2). The shares of other energy sources were as follows: 34% oil, 26.4% coal, 20.9% natural gas and 5.9% nuclear energy. By IEA definition, renewable energy sources include renewable combustibles and waste, hydro, solar, wind and tide energy. Non-renewable waste sources are not included in renewables [7].

Due to its widespread non-commercial use in developing countries, solid biomass is by far the largest renewable energy source, representing 9.3% of world TPES, or 73% of global renewables supply. The second largest source is hydropower, which provides 2.2% of world TPES, or 17.7% of renewables. Geothermal is the third largest renewable source and is much smaller, representing 0.4% of world TPES, or 3.3% of renewables supply in the world. The contribution of "new" renewables (solar, wind and tide) to energy supply is still very marginal, representing approximately 0.2% of world TPES, or 1.6% of renewable supply (Table 2).

Since 1990, renewable energy sources have grown at an average annual rate of 1.7%, which is slightly less than the growth rate of world TPES of 1.9% per annum. Growth has been especially high for wind power, which grew at an average annual rate of 25%. However this is due to its very low base in 1990 and the production still remains small. OECD countries account for most of the production and growth of solar and wind energy. The second highest growth rate was experienced by renewable municipal waste, biogas and liquid biomass. This segment grew on average at 10.4% annually since 1990, yet primary solid biomass, which is the largest contributor to renewable energy in the world, has experienced the slowest growth among the renewable energy sources, with growth rate of 1.2% per annum. Non-OECD countries account for most of the production of solid biomass but its growth is comparable for OECD and non-OECD countries. Solar photovoltaics and solar thermal experienced a 9.8% annual growth rate. The average annual growth rate of hydropower in non-OECD countries, 3.7% between 1990 and 2007, was larger than in OECD countries, which was only 0.4%.

Table 2
World primary energy demand by fuel in the reference scenario (Mtoe).

Energy sources	1980	2000	2007	2015	2030	2007–2030[a]
Coal	1792	2292	3184	3828	4887	1.9%
Oil	3107	3655	4093	4234	5009	0.9%
Gas	1234	2085	2512	2801	3561	1.5%
Nuclear	186	676	709	810	956	1.3%
Hydropower	148	225	265	317	402	1.8%
Biomass and waste[b]	749	1031	1176	1338	1604	1.4%
Other renewables	12	55	74	160	370	7.3%
Total world	7228	10,018	12,013	13,488	16,790	1.5%

[a] Compound average annual growth rate.
[b] Includes traditional and modern uses.

The hydroelectricity generation of non-OECD countries started to exceed that of OECD countries in the year 2001. In 2007, the share of non-OECD countries reached 59.1% and is expected the further increase as most of the remaining hydropotential resides in these countries. On the other hand, the biggest share of solid biomass, 85.9%, is produced and consumed in non-OECD countries, where developing countries, situated mainly in South Asia and sub-Saharan Africa, use non-commercial biomass for residential cooking and heating. Africa, which accounts for only 5.2% of the world's total TPES in 2007, produced 26.2% of the world's solid biomass supply. Energy diversification and a more efficient use of solid biomass are expected to provide mitigation opportunities to sustainability issues regarding the use of biomass in some non-OECD regions [7].

Because of their heavy non-commercial use of biomass, non-OECD countries remain the principal renewables users, accounting for 76% of world total renewables supply. On the other hand, while OECD countries supply only 24% of world renewables, they constitute 45.7% of the world TPES. Consequently, in OECD countries the share of renewables in total energy supply is only 6.5%. This share is 18.3% for non-OECD countries. However the OECD countries play a major role when looking at "new" renewables, with supply of 68.8% of world energy from wind, solar and tide in 2007.

While more than half of the renewable primary energy supply in OECD countries is used in the transformation sector to generate electricity, on a global level a big part of renewables is consumed in the residential, commercial and public services sectors. Again, this is a consequence of widespread biomass use in the residential sector of developing countries. In fact, only 24.4% of renewables are used for electricity production worldwide, while 52.3% are used in residential, commercial and public sectors.

Despite this fact, renewables are the third largest contributor to global electricity production. They accounted for 17.9% of world generation in 2007, after coal (41.6%) and slightly behind gas (20.9%) but ahead of nuclear (13.8%) and oil (5.7%). In the transformation sector, hydro supplies the vast majority of renewable energy, generating 15.6% of world electricity, and 87% of total renewable electricity. Combustible renewables and waste, including solid biomass, play a minor role in electricity

generation, supplying 1.1% of world electricity. Although growing rapidly, geothermal, solar and wind energies accounted for only 1.2% of world electricity production in 2007 [7,8].

Renewable electricity generation grew worldwide since 1990 on average by 2.6% per annum, which is less than total electricity generation with average rate of 3.1%. While 19.5% of global electricity in 1990 was produced from renewable sources, this share fell to 17.9% in 2007. This decrease is mainly the result of slow growth of the main renewable source, hydropower, in OECD countries, which produces about 36% of global renewable electricity.

3. Energy consumption and global warming

Climate change is one of the most difficult challenges facing the world today and preventing will necessitate profound changes in the way we produce, distribute and consume energy. Burning fossil fuels such as coal, oil and gas provides about three-quarters of the world's energy. However, when these same fuels are burned, they emit greenhouse gases (GHGs) that are now recognized as being responsible for climate change. These fuels are ubiquitous. Fossil energy has fuelled industrial development, and continues to fuel the global economy. The primary greenhouse gas emitted through fuel combustion is CO_2. Table 3 shows Energy-related CO_2 emissions by sector in the reference scenario (Mt). Land-use and land-use changes, notably deforestation, also involve emissions of CO_2 [7,32,35].

Global dependence on fossil fuels has led to the release of over 1100 $GtCO_2$ into the atmosphere since the mid-19th century. Currently, energy-related GHG emissions, mainly from fossil fuel combustion for heat supply, electricity generation and transport, account for around 70% of total emissions including carbon dioxide, methane and some traces of nitrous oxide. To continue to extract and combust the world's rich endowment of oil, coal, peat, and natural gas at current or increasing rates, and so release more of the stored carbon into the atmosphere, is no longer environmentally sustainable, unless carbon dioxide capture and storage (CCS) technologies currently being developed can be widely deployed [10,36].

While Turkey has a functional oil exploration and production program under the Turkish Petroleum Corporation, annual crude oil production meets only 10% of the national demand for oil and the remainder is imported from elsewhere in the region. At 42%, oil consumption is the single most important component of Turkish energy consumption and accounts for over 61% of energy imports [23]. Natural gas, which was introduced in the 1980s as a cleaner alternative to coal and lignite, is rapidly becoming an important dimension of energy consumption, even though its domestic production is and will remain very limited. In fact, natural gas is the fastest growing primary energy source in the country. It currently makes up 15.1% of national primary energy consumption and nearly a quarter of all energy imports [20]. On the other hand, at 25.3% of national production and 9.7% of national consumption, biomass and other renewable energy resources remains an important dimension of energy policies in Turkey. However, the contribution of the biomass resources in the total energy consumption dropped from 20% in 1980 to 9.7% in 2005 [23].

Table 3
Energy-related CO_2 emissions by sector in the reference scenario (Mt).

Energy consuming sectors	1990	2007	2020	2030
Power generation	7471	11,896	14,953	17,824
Other energy sector	1016	1437	1755	1993
Industry	3937	4781	5571	6152
Iron and steel	938	1470	1702	1796
Non-metallic minerals	505	818	822	810
Other industry	2493	2493	3047	3546
Transport	4574	6623	7733	9332
Road	3291	4835	5646	6920
Aviation	538	742	884	1067
International shipping	358	613	685	780
Other transport	387	433	518	564
Residential	1891	1877	2031	2198
Services	1066	878	972	1096
Agriculture	405	433	423	437
Non-energy use	581	900	1087	1195
Total world	20,941	28,826	34,526	40,226

4. Energy supply and hydropower production in Turkey

The nature of the energy supply is dependent on two main factors: resource availability and price. Resource availability refers to the geological, geographic and climatic conditions that shape available energy production. While certain policy tools can help discover energy sources or make their processing more efficient, resource availability is largely an exogenous variable that cannot be easily changed. Certain policy interventions, however, could have a dramatic impact on shaping the relationship between geological, geographic and climatic conditions and energy production. For example, in a country endowed with rich wind resources, policies supporting wind-energy technologies can hold great potential [4,21].

The price factor denotes both the relative and absolute cost of energy imports or production and is also largely independent of policy interventions. For example, international markets determine the price of oil and, with the possible exception of the US, countries cannot devise policies to influence it. The cost of converting primary sources to energy supply, however, could be influenced by technology policies that can either make energy production more effective or eliminate the need for importing advanced technologies, such as nuclear power reactors. Similarly, the state in Turkey is in a position to decide between competing technological solutions, such as hydro, wind, and nuclear energy [4,21].

Energy access for all will require making available basic and affordable energy services using a range of energy resources and innovative conversion technologies while minimizing GHG emissions, adverse effects on human health, and other local and regional environmental impacts. To accomplish this would require governments, the global energy industry and society as a whole to collaborate on an unprecedented scale. The method used to achieve optimum integration of heating, cooling, electricity and transport fuel provision with more efficient energy systems will vary with the region, local growth rate of energy demand, existing infrastructure and by identifying all the co-benefits [5,6,36].

The wide range of energy sources and carriers that provide energy services need to offer long-term security of supply, be affordable and have minimal impact on the environment. However, these three government goals often compete. There are sufficient reserves of most types of energy resources to last at least several decades at current rates of use when using technologies with high energy-conversion efficient designs. How best to use these resources in an environmentally acceptable manner while providing for the needs of growing populations and developing economies is a great challenge [5,6,10,25,26,36].

The transition from surplus fossil fuel resources to constrained gas and oil carriers, and subsequently to new energy supply and conversion technologies, has begun. However it faces regulatory and acceptance barriers to rapid implementation and market competition alone may not lead to reduced GHG emissions. The energy systems of many nations are evolving from their historic dependence on fossil fuels in response to the climate change threat, market failure of the supply chain, and increasing reliance

on global energy markets. A rapid transition toward new energy supply systems with reduced carbon intensity needs to be managed to minimize economic, social and technological risks and to co-opt those stakeholders who retain strong interests in maintaining the status quo. The electricity, building and industry sectors are beginning to become more proactive and help governments make the transition happen. Sustainable energy systems emerging as a result of government, business and private interactions should not be selected on cost and GHG mitigation potential alone but also on their other co-benefits [10,36].

5. Hydropower as a renewable energy source

In the last two years, representatives from more than 170 countries have reached a consensus by declaring all hydropower to be renewable and worthy of international support, first at the world summit on sustainable development in Johannesburg (2002), and again at the 3rd world water forum in Kyoto (2003). Some of the supporting evidence for this is summarized below [9,27,36]:

- Hydropower is a renewable source of energy,
- Hydropower supports the development of other renewables,
- Hydropower fosters energy security and price stability,
- Hydropower contributes to fresh water storage,
- Hydropower improves electric grid stability and reliability,
- Hydropower helps fight climate change,
- Hydropower improves the air we breathe,
- Hydropower makes a significant contribution to development,
- Hydropower means clean, affordable power for today and tomorrow,
- Hydropower is a key tool for sustainable development.

The hydropower industry is closely linked to both water management and renewable energy production, and so has a unique role to play in contributing to sustainable development in a world where billions of people lack access to safe drinking water and adequate energy supplies. On the other hand, approximately 1.6 billion people have no access to electricity and about 1.1 billion are without adequate water supply. However, resources for hydropower development are widely spread around the world. Potential exists in about 150 countries, and about 70% of the economically feasible potential remains to be developed-mostly in developing countries where the needs are most urgent [5,6,18,19,27,34,35].

Hydropower is available in a broad range of project scales and types. Projects can be designed to suit particular needs and specific site conditions. As hydropower does not consume or pollute the water it uses to generate power, it leaves this vital resource available for other uses. At the same time, the revenues generated through electricity sales can finance other infrastructure essential for human welfare. This can include drinking water supply systems, irrigation schemes for food production, infrastructures enhancing navigation, recreational facilities and ecotourism [14,16,34,35].

Water is a vital resource that supports all forms of life on earth. Unfortunately, it is not evenly distributed by season or geographical region. Some parts of the world are prone to drought, making water a particularly scarce and precious commodity. In other parts of the world, floods that cause loss of life and property are major problems. Throughout history, dams and reservoirs have been used successfully in collecting, storing and managing water needed to sustain civilization. Hydropower often supports other essential water services such as irrigation, flood control and drinking water supplies. It facilitates the equitable sharing of a common vital resource [2,9,34].

Hydropower has very few greenhouse gas emissions compared with other large-scale energy options. This will be increasingly important in the context of global warming, which implies an expected rising variability in precipitation frequency and intensity. Hydropower projects do not export impacts such as acid rain or atmospheric pollution. Environmental impacts are limited to changes in the watershed for the dam is located. When well managed, these changes can sometimes result in enhancements, and other impacts can be avoided, mitigated. Hydropower can contribute to mitigating the widespread potential human impacts

Table 4
Advantages and disadvantages of the hydropower option.

Advantages	Disadvantages
Economic aspects	
Provides low operating and maintenance costs	High upfront investment
Provides long life span (50–100 years and more)	Precipitation
Provides reliable service	Requires long-term planning
Includes proven technology	Requires long-term agreements
Instigates and fosters regional development	Requires multidisciplinary involvement
Provides highest energy efficiency rate	Often requires foreign contractors and funding
Creates employment opportunities and saves fuel	
Social aspects	
Leaves water available for other uses	May involve resettlement
Often provides flood protection	May restrict navigation
May enhance navigation conditions	Local land-use patterns will be modified
Often enhances recreation	Waterborne disease vectors may need to be checked
Enhances accessibility of the territory and its resources	Requires management of competing water uses
Improves living conditions	
Sustains livelihoods (fresh water, food supply)	
Environmental aspects	
Produces no pollutants but only very few GHG emiss.	Inundation of terrestrial habitat
Enhances air quality	Modification of hydrological regimes
Produces no waste	Modification of aquatic habitats
Avoids depleting non-renewable fuel resources	Water quality needs to be managed
Often creates new freshwater ecosystems with increased productivity	Temporary introduction of methylmercury into the food chain needs to be monitored/managed
Enhances knowledge and improves management of valued species due to study results	Species activities and populations need to be monitored
Helps to slow down climate change	Barriers for fish migration, fish entrainment
Neither consumes nor pollutes the water it uses for electricity generation purposes	Sediment composition and transport may need to be monitored/managed

Source: [9].

Table 5
Technically and economically feasible hydropower potential of the world in 2005 by region.

Region	Gross theoretical (TW/year)	Technically feasible potential (TW/year)	Economically feasible potential (TW/year)	Installed hydro capacity (GW)	Hydropower production (TW/year)
North America	8054	3012	912	141.2	697
L. America and Caribbean	7121	3030	1199	114.1	519
Western Europe	3294	1822	809	16.3	48
European Union	195	216	128	9.1	27
Russian-Federation	2295	1670	770	146.6	498
Middle East	418	168	128	21.3	66
Total Africa	3883	1860	1288	65.7	225
South Asia	3635	948	103	28.5	105
Pacific Asia	5520	814	142	13.5	41
Pacific OECD	1134	211	184	34.2	129
World total	41,202	16,494	6965	654.8	2581

Source: [9].

of climate change. Table 4 shows advantages and disadvantages of the hydropower [9,34].

There is no single solution to the world's quest for more, cleaner energy and effective water management [26,33]. Energy and water for sustainable development depend not only on supply choices, but also on how these choices are implemented. It requires the creation of a level playing field among available energy options and global water governance involving all stakeholders in a participatory decision-making process [27,34]. In adopting their own sustainability guidelines, the members of the International Hydropower Association (IHA) are committed to developing and operating their projects, in collaboration with all stakeholders, in a way that is environmentally friendly, socially responsible and economically efficient so that hydropower projects can make a major contribution to achieving sustainable energy development [9,34].

There is about 700 GW of hydro capacity in operation worldwide, generating 2740 TWh in 2002 (about 19% of the world's electricity production) [5]. About half of this capacity and generation is in Europe and North America with Europe the largest at 32% of total hydro use and North America at 23% of the total. However, this proportion is declining as Asia and Latin America commission large amounts of new hydro capacity. On the other hand, small, mini and micro-hydroplants (usually defined as plants less than 10 MW, 2 MW and >100 kW, respectively) also play a key role in many countries for rural electrification. An estimated 300 million people in China, for example, depend on small hydro [2,5,6,34].

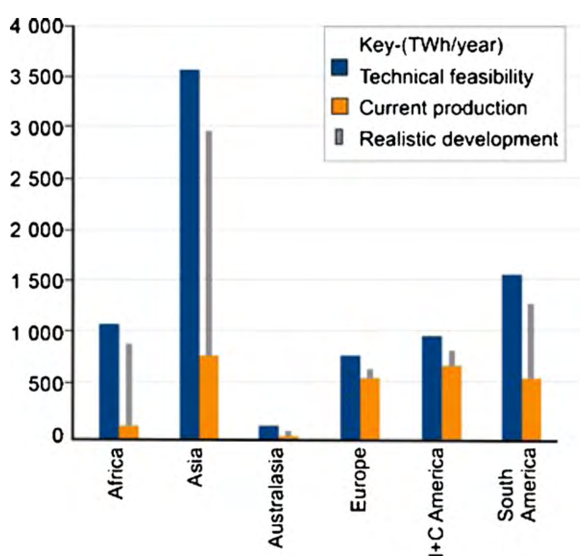


Fig. 1. Estimated hydropower development by region [9].

As shown in Table 5 the world's gross theoretical hydropower potential is about 40,000 TWh/year, of which about 14,000 TWh/year is technically feasible for development and about 7000 TWh/year is currently economically feasible. The last figure fluctuates most being influenced not only by hydro technology, but also by the changing competitiveness of other energy/electricity options, the status of various laws, costs of imported energy. As can be seen from this table, the biggest growth in hydro generation is expected in the developing countries, while relatively little growth is expected in most OECD countries where more than 65% of the economic potential is already in use. Fig. 1 also shows estimated hydropower development by region in the world [9]. Thus, at least in the near future, hydro will likely remain the main source of electricity generation in developing countries that possess adequate water resources [2,34].

Until recent years there has been less than 100 GWh/year of new hydro capacity under construction at any one time, equivalent to less than 15% of the capacity in operation. The figure has now risen, reflecting China's vast construction program includes the 18.2 GW. Most new hydro capacity is under construction in Asia and South America. China has by far the most, with about 50 GW under way. Brazil has largest resources in world (800,000 GWh/year) of economically exploitable capacity and Norway depends almost entirely hydro for its electricity needs [5,6,34].

6. Hydropower and sustainability in Turkey

In Turkey renewable energy supply is dominated by hydropower and biomass, but environmental and scarcity-of-supply concerns have led to a decline in biomass use, mainly for residential heating. Total renewable energy supply declined from 1990 to 2004, due to a decrease in biomass supply. As a result, the composition of renewable energy supply has changed and wind power is beginning to claim market share. As a contributor of air pollution and deforestation, the share of biomass in the renewable energy share is expected to decrease with the expansion of other renewable energy sources [17]. Table 6 shows Development of irrigation,hydropower and water supply in Turkey.

Turkey has aimed at increasing domestic production by public, private and foreign utilities, at increasing efficiency by rehabilitation of existing plants and acceleration of existing construction programs. On the other hand, there are 436 sites available for hydroelectric plant construction, distributed on 26 main river zones. The total gross potential and total energy production capacity of these sites are nearly 50 GW and 112 TWh/year, respectively and about 30% of the total gross potential may be economically exploitable. At present, only about 35% of the total hydroelectric power potential is in operation [1,30,31].

At present, the average hydroelectric capacity in Turkey is 45 TWh/year which corresponds to only 36% of the total economically feasible potential of the country. Up to 2020, it is

Table 6
Development of irrigation, hydropower and water supply in Turkey.

	In operation (2005)	Ultimate goals (2030)	Development rates (%)
Irrigation	4.9 million ha	8.5 million ha	58
Hydroelectric energy	45.3 billion kWh	127.3 billion kWh	36
Water supply	10.5 billion m^3	38.5 billion m^3	27

Source: [1].

expected that about 502 new hydropower plants will be constructed to make use of the full available potential [1,24,28,32,33].

Hydroelectricity is well established as one of the principal energy-producing technologies around the world, providing some 20% of the world's electricity. In the developing countries, the proportion rises to around 40%. The capacity of large hydroelectric schemes can be several times that of a conventional power station. They are highly efficient, reliable, and long lasting. They are also very controllable and add an element of storage into an electricity supply system, thereby allowing compensation for the varying intensity of other renewable energy sources and for variations in electricity demand. However, the dams and their large lakes forms also have major environmental and social impacts [11,15,18,19,29–34].

Turkey has important hydropower potential and has rigorous plans for the development of its substantial potential. Approximately 5500 MW of hydropower capacity is under construction, the largest schemes being Deriner Dam in the north of the country (680 MW) and Berke Dam in the southeast (520 MW). In Turkey, 566 hydropower projects by DSI (State Hydraulic Works) [1] have been identified for development in total, 130 are already in operation, 31 are under construction, and 405 (with a capacity of 19 951 MW) are planned. Table 7 shows present and potential of hydroelectric power in Turkey (2006). Fig. 2 shows distribution of Turkey's hydropower potential.

By the year 2010, Turkey is planning to exploit two-thirds of its hydropower potential, aiming to increase hydro-production to about 75,000 GWh/year. By 2020 this will rise to 100,000 GWh/year, and by 2030 it could be 140,000 GWh/year [1]. On the other hand, There are 436 sites available for hydroelectric plant construction, distributed on 26 main river zones. The total gross potential and total energy production capacity of these sites are nearly 50 GW and 112 TWh/year, respectively. As an average, 30% of the total gross potential may be economically exploitable. At present, only about 18% of the total hydroelectric power potential is exploited. The national development plan aims to harvest all of the hydroelectric potential by 2010 [12,13,15,22,34].

During last three decades, the average annual increase of small hydropower plant (SHP) capacity was 5–10%. As of 2004, the total development of SHP capacity that is accepted as small hydropower according to the Electrical Power Resources Survey and Development Administration (EIE) [3], which is less than 10 MW, in Turkey

Table 7
Present and potential of hydroelectric power in Turkey (2006).

	Number of power stations	Total installed capacity (MW)	Proven production (GWh/year)	Total annual production (GWh/year)
Present hydropower plants				
In production > 10 MW	74	193	287	722
In production < 10 MW	68	12,595	33,273	45,208
Under construction > 10 MW	8	45	151	228
Under construction < 10 MW	32	3152	6207	10,290
Present total	182	15,985	39,918	56,448
Future possible potential				
>5 MW	164	366	571	1,848
5–10 MW	82	610	897	2,587
10–50 MW	187	4727	9234	18,959
50–100 MW	51	3692	7734	13,001
100–250 MW	37	5,815	11,824	19,308
240–500 MW	10	3250	5620	10,688
500–1000 MW	2	1053	2054	3,173
1000 < MW	1	1200	2459	3,833
Future total	534	20,713	40,393	73,398
Total	716	36,698	80,311	129,846

Source: [1].

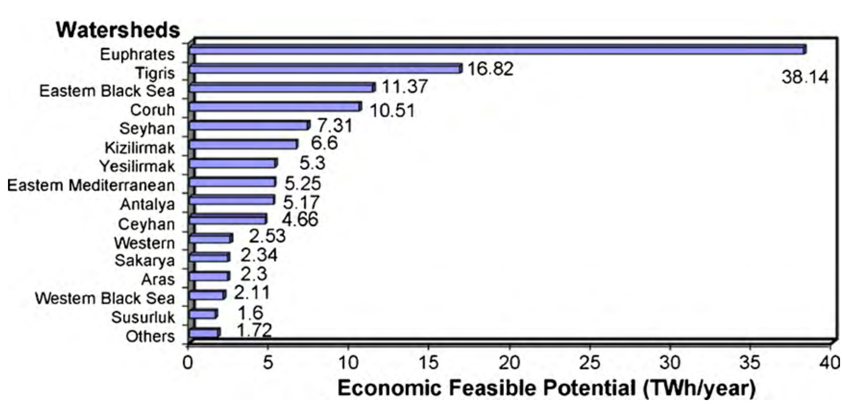


Fig. 2. Distribution of Turkey's hydropower potential on basin level [1].

was 850 MW, and total annual energy production was 150 MW of 4125 GWh. However, 130 MW of these power plants were managed, and their annual firm production and average production were 260 and 510 GWh, respectively [1]. At the beginning of 2005, total number of SHP plants in operation throughout the country was 62, with a total installed capacity of 190 MW, about 1.5% of the total hydropower potential in Turkey.

Total installed projects capacity of SHP is 2.45% and the total energy potential is about 2.96%, which have installed capacity less than 10 MW. At the end of 2004, about 96% of the all ready-exploited potential is from dams and HEPPs, and the remainder is from run-off river and canal SHP. Neglecting the geothermal, wind, and solar generation, about 65% of the electricity is produced by thermal power plants, and hydropower plants produce about 35% of the remaining electricity.

7. Conclusions

Turkey is an energy importing nation with more than 65% of our energy requirements met by imported fuels. Air pollution is becoming a significant environmental concern in the country. In this regard, hydropower and other renewable energy sources are becoming attractive solution for clean and sustainable energy future of Turkey. Hydropower installed capacity increased by 5.2% per year from 1990 to 2003. Hydropower contributed 22.2% of total renewable energy supply and 2.8% of TPES in 2003.

Hydropower is a proven, well understood technology based on more than a century of experience. Its schemes have the lowest operating costs and longest plant lives. Upgrades and refurbishment of generating plant can readily extend scheme life. Hydropower plants also provide the most efficient energy conversion process [34]. Modern plants can convert more than 95% of moving water's energy into electricity, while the best fossil-fuel power plants are only about 60% efficient. Hydropower also has the highest energy payback ratio. During the lifetime of a scheme, it can produce more than 200 times the energy needed to build it.

On the other hand, Turkey is an energy importing nation with more than 70% of energy requirements met by imported expensive fuels. Air pollution is becoming a significant environmental concern in the country. In this regard, hydropower and other renewable energy sources are becoming attractive solution for clean and sustainable energy future of Turkey. Turkey's abundant hydropower potential is among the highest in Europe, but only one-third of this capacity is utilized. Turkey's total hydropower capacity is estimated at 433 TWh/year. Also the economically feasible hydroelectric potential is estimated at about 125 TWh/year and the installed capacity is 35,000 MW/year. Hydropower installed capacity increased by 5.0% per year from 1990 to 2005. Hydropower contributed 21% of total renewable energy supply and 2.7% of total primary energy supply in 2005. As a result, hydropower is very important for Turkey to generate electricity and supply water [36].

The hydropower industry is closely linked to both water management and renewable energy production and thus has an important role, in cooperation with the international community, and in striving for sustainable development in a world where billions of people still lack access to safe drinking water and adequate energy supplies. Hydropower emits very few greenhouse gases in comparison with other large-scale energy options and thus helps slowing down global warming. In addition, by storing water in rainy seasons and releasing it in dry ones, dams and reservoirs help control water during floods and droughts. These essential functions, protecting human lives and other assets, will be increasingly important in the context of climate change is expected to give rise to even greater variability in the frequency and intensity of rainfall.

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